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Climate change adaptation and EIA in Austria and Germany – Current consideration and potential future entry points

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1. Introduction

In order to reduce susceptibility of projects to potential negative impacts of climate change (CC) and associated wider environmental effects, early consideration in planning processes is important. Environmental impact assessment (EIA) can provide a point of entry for the incorporation of CC impacts and adaptation within existing modalities of project design, approval and implementation (e.g. Fischer et al., 2016; Agrawala et al., 2010; Runge et al., 2010; Byer et al., 2012; Walker et al., 2013; EC, 2013a). Following the revised European EIA Directive (2014/52/EU), since May 2017, both, CC mitigation and adaptation need to be considered in EIA prepared in EU member states.

Various authors have suggested that impacts of a changed environment and a changed sensitivity of environmental issues should be considered in EIA (e.g. Balla et al., 2017; Wachter et al., 2017; Jiricka et al., 2014; EC – European Commission, 2013a). In this context, Jiricka et al. (2014) suggested the following typology for the consideration of CC-related impacts (see also Runge and Wachter, 2010a,b; Runge et al., 2010 and Birkmann et al., 2012):

- direct impacts of CC on projects (e.g. increased number of extreme heat days as well as storm events that may cause damage to road or railway infrastructure);
- impacts on projects that are indirectly associated with the project environment (e.g. drought and periods of extreme heat days that might increase the likelihood for forest fires; storm events that can cause windfall of trees);
- direct impacts on the environment surrounding the project (e.g. drought that can impact wetland habitats or decrease the efficiency of mitigation measures for them; barrier effects that could have a stronger impact on amphibians moving between different habitats).

In this paper, the inclusion of CC in existing EIA practice is explored and possible CC entry points are established. The focus is on Austria and Germany, two EU member states in which suggestions for the consideration of CC adaptation into regional and urban/local planning have been made on various occasions (Birkmann et al., 2012; MKRO, 2013; BMVBS, 2013; Spiekermann and Franck, 2014; Born et al., undated; Jacoby and Beutler, 2013). However, to date the discussion of potential CC impacts on projects and their associated environments has remained underdeveloped (Runge et al., 2010; EBA, 2014; Kunze et al., 2014; Jiricka et al., 2014; Balla et al., 2017; Wachter et al., 2017).

Dealing with CC in a specific local context is a challenge for those involved, including project developers, authorities, assessors and planning officers. In order to help addressing this challenge, this paper tackles the existing "science-policy-practice-divide" with regards to CC consideration in EIA in Austria and Germany.

To date, only few authors have reflected on CC integration into EIA. Jiricka et al. (2016) analysed the perception of actors on barriers and enablers for CC consideration in EIA. Kamau and Mwaura (2013), Larsen (2014), Hands and Hudsun (2016) and Enríquez-de-Salamanca et al. (2016) looked at how climate change was acknowledged in EIA in general terms. Furthermore, environmental impacts of CC adaptation measures (climate proofing) were studied by Enríquez-de-Salamanca et al. (2017).

This paper is based on a research project which was funded by the Austrian Climate Research Program (ACRP) and which ran from 2016 to 2018. Based on the outcomes of the project, subsequently, we will not only reflect on the existing integration of CC into EIA, but also establish possible thematic "entry points". In this context, the current range of meteorological phenomena, also referred to as "climate/climatic factors" (EC, 2013a; EC, 2013c) are the starting point, as these are likely to be influenced by CC. Practice in three types of linear infrastructure projects is explored, including high-speed railways,

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motorways/express roads and electrical power lines.

2. Background

EIA can lead to an improved consideration of CC impacts in project planning (McCallum et al., 2013; Walker et al., 2013; EC, 2013a; EC, 2013b; Byer et al., 2012; Agrawala et al., 2010; Runge et al., 2010; CARICOM, 2004; CEAA, 2003; Fischer et al., 2011; Fischer and Sykes, 2009; Bhave et al., 2016). Obstacles and challenges for inclusion have been discussed by e.g. Enríquez-de-Salamanca et al. (2016) and Jiricka et al. (2016). A range of guidelines and work aids exist, at international (OECD, 2009) and national levels (CEAA 2003; Nova Scotia Environment (Canada), 2011; Draaijers and van der Velden, 2009; Environmental Assessment Team, 2010; Balla et al., 2017). These guidelines refer to a number of challenges for CC inclusion in EIA in Austria and Germany, revolving around planning deficits, uncertainties and adaptation deficits. In German speaking countries, environmental guidelines for rail infrastructure (Roll et al., 2014) are the first to recommend preparation of climate compatibility studies for various steps of EIA, drawing on most relevant and recent CC prognoses.

The main focus of many studies (e.g. Koetse and Rietveld, 2009; Regmi and Hanaoka, 2011; Swart and Biesbroek, R. 2008; Boyle et al., 2013), reports (Department of Transport, 2014; Infrastructure Canada, 2006; Nemry and Demirel, 2012) and guidelines (e.g. Bles et al., 2015 and Dallhammer et al., 2015) that have covered CC adaptation to date has been on increasing resilience of projects to CC impacts (climate proofing). Impacts on the surrounding environment are also illustrated and discussed in general terms by the European Commission (2013a and 2017) for EIA and also SEA. Furthermore, there is guidance focusing on specific aspects, including e.g. UNECE Water (2009). Here, cases are provided for how climate scenarios (climate projections) can be incorporated into hydrological models, thus supporting the assessment of the vulnerability of water in a given country or region, using a climate vulnerability index. Other examples of good practice and approaches for the integration of CC adaptation in EIA are provided by May et al. (2016).

Despite the potential of impact assessments to support consideration of CC adaptation, authors such as Larsen (2014), Hands and Hudsun (2016) as well as Kamau and Mwaura (2013) and Enríquez-de-Salamanca et al. (2016) have suggested that the extent to which this is happening in practice is currently only partially known. It is within this context that the paper is shedding light on the current consideration of CC adaptation into EIA and is exploring entry points of CC into EIA.

3. Methodological approach

For the evaluation of EIA documents for road, rail and high-voltage power infrastructure projects, a comprehensive catalogue of search terms was compiled by experts from BOKU University in Vienna and the Environment Agency Austria (UBA; see Section 3.3 and Table 2). The associated content analysis of EIA documents was conducted from June to September 2016.

3.1. EIA sample

Twenty-three EIAs from Austria (2005–2016) and 28 EIAs from Germany (2010–2016) were evaluated. Altogether, 2956 Austrian and 2849 German digital files were reviewed ("files" include e.g. individual chapters and various annexes of environmental impact statements). This means that an average of 129 files for each EIA in Austria and of 102 files for each EIA in Germany were studied. The files were from the project approval stage and were part of either:

- the Environmental Impact Statement (EIS);
- technical documents; or
- statements from authorities and for Austria, also from members of the public.

Furthermore, in Austria, an existing database on EIA related documents (centrally kept by the Federal Environment Agency) allowed for an analysis of final notifications of decisions. In total, nine federal road projects and 12 rail projects from Austria were analysed (all high-performance routes, comprising linear projects and large station projects). Only two high-voltage power projects were available digitally (see Annex). All selected road and power line projects concerned the construction of newly planned routes. With regards to rail projects, two tunnels (Brenner and Semmering base-level tunnels) represented - at least in parts - new transport routes, while all other projects were about the construction of additional tracks to existing infrastructure (upgrades to high-performance routes).

The 28 EIAs from Germany comprised all types of landscapes (e.g. mountains, central uplands, northern lowland and riparian landscapes). As in Austria, new projects as well as upgrades of existing infrastructure were included. Altogether, 12 high-voltage power transmission projects, seven rail projects and nine road projects were included (see Annex).[1]

In both, Austria and Germany, EIA is linked to permit procedures. In Austria, but not in Germany, EIA follows a one-stop-shop approach, allowing to address all permits together (e.g. hydrological engineering and geology related). This difference between the two countries means the potential influence of framing conditions for integrating CC adaptation can be critically reflected on (Jiricka-Pürrer et al., 2018).

3.2. Survey design

Content analysis was organised along two stages (see Fig. 1). First, whether a direct reference to CC is made was established. Second, files were searched for the mentioning of meteorological phenomena that could be associated with potential CC impacts (CC signals/stressors). Combinations of both were also established. For this purpose, a maximum distance of 60 words between the mentioning of a source (phenomenon/stressor) and an impact was used. This maximum word distance was established after analysing a large random sample of documents, establishing links between predicted source (phenomenon) and CC impacts. A cross-check through the subsequent qualitative analysis of all relevant citations on the existence of any combinations beyond these 60 words was also applied.

Single-term search rounds were conducted for meteorological phenomena (CC stressors) and potential CC impacts/relevant aspects. Documents were indexed and searched with *Apache Solr* software (allowing proximity and regular expression search), using *python* for automation. *OpenRefine* was used to process raw XML output and convert it to MS Excel spreadsheets, linked to the initial documents. Results were subsequently evaluated qualitatively by the project team and were classified according to their relevance (see Section 3.4 and Table 3). Specific attributes were allocated. Furthermore, key quotes were identified. Coding was conducted with a focus on (a) matters of relevance to the altered sensitivity of individual environmental issues, and (b) the consequences for a project (what is often called climate proofing).

3.3. Content analysis

The content analysis consisted of a two-stage process; first, files were checked for direct references to CC for determining relevance. The following search terms were used (note that this was done in German; English words represent the best possible equivalent):

[1] Multiple procedures were included for single projects in Germany. Thus, for the 7 sections of the coastal motorway A 20, 7 separate procedures were conducted; here, files for Sections 1 and 6 were available.

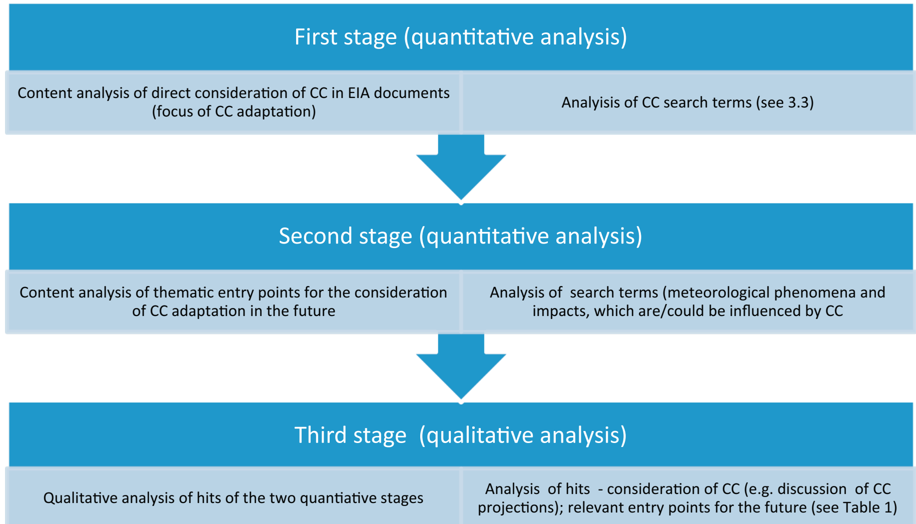


Fig. 1. Methodological approach of content analysis.

- climate change (Klimawandel)
- climatic change (klimatische Veränderungen)
- climate change impacts (Klimawandelfolgen/Klimafolgen)
- climate change adaptation (Klimawandelanpassung/Klimaanpassung)
- vulnerability (Vulnerabilität)
- scenario (connected with climate change) (Klimaszenarien/Klimaprojektionen)

Next, a content analysis of climate stressors was conducted. These are composed of certain meteorological phenomena exacerbated by CC (e.g. "strong storms" or "heavy precipitation") and associated impacts (e.g. "wind throw" or "slope slumping"). The search term catalogue for the second stage (see Table 1) focused on meteorological phenomena possibly already influenced by CC or likely to be affected in the future.

Climate stressors were identified based on international (EC-European Commission, 2013b and c) and national adaptation strategies (BMLFUW, 2017; BMU, 2009; BMU, 2011) as well as based on results of previous research projects (Dallhammer et al., 2015; Jiricka et al., 2016; Balla et al., 2017) along with the results of a literature review.

Furthermore, experts were consulted (see Table 2). Meteorological phenomena correspond with those discussed in other studies on CC adaptation, for example, the European Environment Agency (2017). In order to facilitate evaluation, environmental issues expected to be

Table 2
Consultations for the compilation of the criteria catalogue for ex-post evaluation.

Institution	Institute/department	EIS environmental issue
BOKU	Institute of Mountain Risk Engineering	Soil, Water
BOKU	Institute of Applied Geology	Soil
BOKU	Institute of Soil Research	Soil
EAA	Dpt. Soil and Spatial Management	Soil
BOKU	Institute of Hydrobiology and Aquatic Ecosystem Management	Water
BOKU	Institute of Water Management, Hydrology and Hydraulic Engineering	Water
UBA	Dpt. Surface Waters	Water
EAA	Dpt. Groundwater	Water
BOKU	Institute of Zoology	Fauna
BOKU	Institute of Wildlife Biology and Game Management	Fauna
BOKU	Institute for Integrative Nature Conservation Research	Biodiversity/habitat
BOKU	Institute of Botany	Flora
EAA	Dpt. Biodiversity and Conservation	Flora/fauna/ biodiversity
BOKU	Institute of Silviculture	Fauna/forest ecology

Table 1
Catalogue of search terms – second stage (original German search words and translation).

Meteorologische Phänomene (= Klimasignale)	Klimawandelfolgen/klimawandelrelevante Aspekte	Meteorological phenomena (climate stressors)	Climate change impacts/aspects which can lead to CC impacts
Starkregen (Großräumig)	Überschwemmungen	Heavy precipitation	Flooding
Starkregen (Kleinräumig)	Erosion/Hangrutschungen	Heavy precipitation	Erosion/landslide
Trockenheit	Dürre	Aridity	Drought
Trockenheit	Niedrigwasser	Aridity	Low water levels
Schneefall/Schneestürme	Sturmschäden/Schneebruch	Snow storms	Storm damages due to wet snow
Eisregen	Vereisung/Eisbruch	Freezing rain	Icing/ice-breaking up
Frost/Tauwechsel	Rutschungen/Erosion/Permafrostdegradation	Freeze thaw weathering	Landslide/permafrost melt
Kältewelle	Extreme Kälte	Cold waves	Extreme cold
Hitzewellen	Hitzestress/Hitze- und trockenheitsbedingte Brände	Heat waves	Heat waves/fire
Mittlere Temperaturverschiebung	Temperaturvariabilitäten/Veränderung des Jahresgangs	Temperature rise	Temperature variability
Kleinräumige Gewitterstürme	Sturmschäden inklusive Windwurf	Storm	Strom damage Wind erosion
Großräumige Stürme	Sturmschäden inklusive Windwurf	Storm	Wind trow

Table 3
Classification of relevance in ex-post evaluation.

Classification of relevance	Criteria for classification	Marker
No relevance	Mentioning of term, however, having a different meaning (e.g. species or place names) and not being impact relevant	Red
Low relevance	Mentioning of a phenomenon or CC impacts without relevance for the specific EIA context	Orange
Relevance	Mentioning of a phenomenon or CC impacts in the specific EIA context; mentioning of an additional search term related to CC in the specific EIA context	Light green
High relevance	Combined mentioning of meteorological phenomenon and associated CC impacts in a shared EIA context, mentioning of a phenomenon or CC impacts with direct reference to CC (and impacts) in the same text passage	Dark green

affected by the respective CC impacts were added.

3.4. Classification of relevance

Results of the content analysis were critically reviewed by the project team. An overview of the classification of relevance is presented in Table 3.

Search term hits outside the CC impact context were marked as “not relevant”, such as species or place names. The same applies to hits that explicitly refer to a lack of impact, e.g.

> *“Snow pressure and snow breakage is highly unlikely in the study area, since these damages are usually concentrated in the wet snow zone (600-800 m above sea level)”.*

Likewise, hits were counted as “not relevant” if they merely referred to the treatment of a search term in another chapter, e.g.

> *“For floods and landslides, see the expert opinion of the Department for Torrent and Avalanche Protection”.*

The mentioning of CC impacts without directly connecting them with EIA was classified as being of “low relevance”. This includes, for example, the mentioning of legal provisions for considering CC impacts, without there being any direct connections with the project or case (e.g. “flood zone”). It also includes “descriptions of standards”, where no environmental issue-specific impacts are expected due to CC, for example:

> *“Measure must be implemented before the first snow”.*

The classification “relevant” was allocated whenever a phenomenon/CC impact was discussed in EIA, referring directly to the respective environmental issue/project. The same applies to the use of scenarios, prognoses, trends, discussions with a reference to CC, for example:

> “*Another scientific claim is that the summers will become drier in the coming decades and centuries, and will bring more heat and aridity/drought.*”

> “*...potential impact of the groundwater and mountain water regimes could occur due to the project. Forests in this area will be affected by such an impact since a drying of forest floors is expected, which could lead to a change of site conditions in the mid to long term, and to a shift of tree species assemblage towards species that are more resilient to aridity*.”

Table 4 gives an overview of the information collected together with the data analysis per each hit of a search term.

3.5. Limitations

As explained above, results from Austrian and German EIA practices are not readily comparable. Reasons are the different climatic and topographic conditions on the one hand (associated with two countries of partly different geographies, with Germany being over four times the size of Austria), and a difference in the number of documents on the other. Due to the slightly different sample sizes for each infrastructure type, results need to be interpreted with caution (e.g. percentages of each sub-sample). To overcome this limitation, an in-depth qualitative interpretation is provided. This approach also helps in interpreting possible differences associated with the inclusion of additional documents in Austria (i.e. final permitting stage related).

Table 4
Content of analysis matrix.

Contents of the analysis matrix:
- the quote from the document in which the search term occurred (approx. 100 words)
- its relevance
- summary of the topic addressed in the quote
- possible comments on the quotes
- the meteorological phenomenon addressed, provided this is evident from the quote
- the climate change impact or climate change-relative aspect addressed, provided this is evident from the quote
- the section of the EID (EIS) in which the search term occurred (e.g. assessment of current-state, project impact on environmental issues, measures)
- project type (road, rail, high-voltage power transmission)
- project title
- search term category (pre-check, combination search or search for additional terms)
- document type (general EID report, technical report, specialist report, addendum/amendment, statement, expert opinion on environmental impact, approval notice)
- year in which the respective document was released
- office/institution that released the document
- page number of the quote within the document
- continuous quote number as a unique identifier
- team member processing the quote
- internal file number of the project (in Austria)
- and a link to the respective file.

4. Results

Results are presented on the existing consideration of CC adaptation (4.1) as well as on the consideration of meteorological phenomena that may serve as entry points for future CC integration (“climate stressors” (4.2)).

4.1. Consideration of CC in EIA

The analysis of direct references to CC resulted in a very low number of hits. In Austria, 203 hits of search terms directly addressing CC (see 3.3) were found (climate change, climatic change, climate change impacts, climate change adaptation, vulnerability, climate change scenarios). In Germany, 184 hits of all search terms were found. There are differences between the two countries that are associated with the inclusion of the final permitting stage in Austria, which also included written statements by the public. In the Austrian sample, 11% of the hits in the first step of analysis were from this document category. Altogether, there was only little evidence of direct references to the adaptation to CC, though.

Subsequently, thematic entry points for CC into EIA are established. These are associated with CC stressors – meteorological phenomena that are possibly already influenced by CC or likely to be so in the future. The qualitative analysis presented in Section 4.3 shows that a

direct connection with CC is made. In this context, we will also point towards methodological entry points.

4.2. Consideration of thematic entry points in EIA (CC stressors)

First, we present results for the combined analysis of meteorological phenomena and related impacts. The search for meteorological phenomena (CC stressors) with expected changing future frequencies, intensities and/or duration returned a total of only 47 hits in Austria (in 23 EIAs). These contained various combinations of search terms. Of the 16 possible combinations, only three were found, though. The majority of them (32) addressed the combination of "heavy rainfall" and "erosion". Furthermore, a combination of "heavy rainfall" and "flooding" was found five times. Finally, the combination of "aridity" and "drought" was found four times.

In German EIAs, the combination of "flooding" and "heavy rainfall" as well as "heavy rainfall" and "erosion" was found twice only and one relevant citation was provided. Below, the results of the single-term search are presented.

4.2.1. Austrian EIAs

In Austria, the search for single-term CC impacts resulted in 4235 hits from 616 digital files. Of these, 2935 hits were classified as relevant, 589 as being of low relevance and 711 as being not relevant. The two search terms with the greatest number (almost two thirds) of relevant results included "erosion" (1164) and "heavy rainfall" (687). "Wind throw" (413 results), "wind erosion" (314), "aridity" (134) and "flooding" (111) were also frequently mentioned. Comparatively speaking, with 50 results, "slope slumping" as one of the potential consequences of climate change was also referred to frequently. While "low water level", "storm damages" and "drought" were mentioned between 10 and 20 times each, the other eight search terms were referred to only between one and seven times. Table 5 shows the results for hits of all search terms.

Of the total number of 4235 hits (2935 of which relevant), about twice as many are from road EIAs (2665) than from rail EIAs (1276). Graph 1 shows results for each project type. Both, rail and road projects were found to be most affected by "heavy rainfall", while "drought" was mentioned more often in the EIAs for high-voltage power lines than in the EIAs for the other two project types.

Aspects that can be attributed to possible future CC impacts are heterogeneous (see Graph 2). However, for all project types, "erosion" is consistently the most frequently cited aspect. It makes up almost half of all hits in high-voltage power projects, slightly more than half in road projects and about 65% in rail projects. In high-voltage power and road projects, "wind throw" has the second highest frequency, with a proportion of 25% and 30%, respectively. However, it is only in fourth position in rail projects. While "wind erosion" plays an important role in road and rail projects – making up about 15% of hits in both cases, it is mentioned only rarely in connection with high-voltage power projects (approx. 2%). Here "slope sliding" is in third position, making up about 15% of all hits. "Flooding" is found in all three project types, though to a lesser extent. With a proportion of 10%, it is encountered twice as frequently in rail projects than in the two other project types. Rail projects are also affected by "slope sliding", "storm damages" and "low water levels", though to a lesser extent, while high-voltage power transmission lines are said to be affected by "storm" damages, "drought" and "icing".

Table 5
Total number of hits in all documents (Austria), by relevance category.

Search term	Relevant	Low relevance	No relevance	Total
Freeze thaw weathering	1		1	2
Heat wave	1			1
Snow storm	1		6	7
Temperature fluctuation	2	7	6	15
Large-scale storms	2			2
Wet snow	3		4	7
Snowfall	6	1	16	23
Icing	7		201	208
Low water level	11	5	32	48
Storm damages	12	1		13
Drought	17	12	76	105
Slope slumping	49	14	5	68
Flooding	111	96	75	282
Aridity	134	29	103	266
Wind erosion	314	9	13	336
Wind throw	413	29	73	515
Heavy rainfall	687	14	22	723
Erosion	1164	372	78	1614
Total	**2935**	**589**	**711**	**4235**

EIA primarily considers effects of a project on the environment. In this context, CC can lead to an increased susceptibility of environmental issues as well as to risks to the project. Exploring linkages with environmental issues, differences between EIAs for different sectors were observed (see Graph 3). The sub-issue "forest" was addressed in about 40% of high-voltage overhead power line EIA files. "Soil" (nearly 25%) and "natural hazards" (about 10%) were also linked to issues relevant to CC adaptation. "Water", "climate/air", "animals", "plants", "habitats" (except forests) and "humans", on the other hand, were only rarely associated with the search terms. About 10% of the results cannot be attributed to any specific environmental issue.

In the EIA files for road projects, search terms were most frequently found in connection with "forests" (40% of relevant results). "Soil" and "surface water" were also addressed frequently. Results associated with these issues make up about a quarter of all hits. Roughly 10% of the hits in road EIA documents revolve around general changes to "climate".

In rail projects, it is not "forests", but "soil" which is mentioned most frequently (about 30% of relevant hits). "Surface water" also had a large number of hits (more than a quarter of relevant hits). In contrast to the other two project types, "forests" are only addressed in about 10% of rail projects. "Climate" is referred to twice as often in road than in rail projects (10% and 5%, respectively). "Natural hazards", "plants", "animals" and "habitats", as well as "ground water" and "humans", are addressed only rarely. Hits that cannot be attributed to any specific environmental issue make up about 15%.

4.2.2. German EIAs

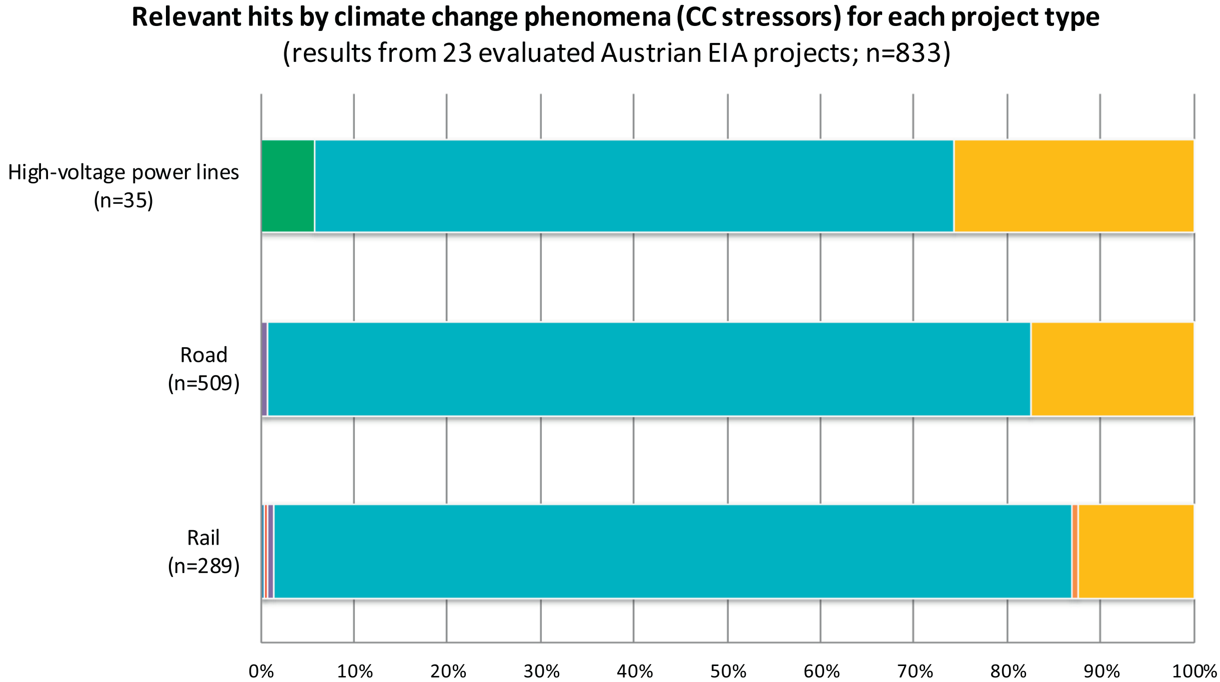
In German EIAs, the search for meteorological phenomena (CC stressors) and potential CC impacts resulted in a total of 733 hits in 117 digital files, representing 28 EIAs. Of these, 298 hits were classified as relevant, 282 as somewhat relevant and 153 as not relevant. By far the most relevant were "wind throw" (37 hits), "heavy rainfall" (65 hits), "erosion" (75 hits) and "flooding" (103 hits), together making up 280 of 298 total relevant hits.

"Flooding", "erosion" and "heavy rainfall" alone made up about 82% of all relevant hits. The other eight search terms together only made up 55 relevant hits (18%). Of these, "wind throw" had 37 relevant hits. Table 6 provides an overview of the search terms and their respective classification of relevance.

When considering project type and meteorological phenomenon, a more varied picture emerges (see Graph 4). In road and rail projects, "heavy rainfall" is most significant, making up almost 100% for the former, and over 80% for the latter. Here, relevant hits concerning "aridity" make up about 18%. In the case of high-voltage power transmission projects, on the other hand, "aridity" dominates with about 86%. "Heavy rainfall" is represented with about 14% of all hits.

With regards to CC relevant aspects and potential CC impacts, each project type is different (see Graph 5). "Flooding", "erosion" and "wind throw" dominate in the case of road and rail projects, with over 90% of relevant hits. For high-voltage power transmission lines, only "erosion" (42%), "wind throw" (19%) and "flooding" (39%) were mentioned.

Analysing the number of relevant hits per environmental issue can



	Rail (n=289)	Road (n=509)	High-voltage power lines (n=35)
Freeze thaw weathering	1		
Large-scale storms			2
Heat wave	1		
Snowfall	2	4	
Heavy rainfall	247	416	24
Temperature fluctuation	2		
Drought	36	89	9

Graph 1. Meteorological phenomena exacerbated by CC (CC stressors) in Austrian EIA documents.

help establish specific environmental impacts and risks for each project type (see Graph 6). In the case of road projects, more than two thirds of all hits referred to “surface water”, usually concerning drainage after heavy rainfall events. “Forest” is the second most seriously affected environmental issue for this project type with about 10% of all hits. Since “forests” are referred to in connection with wind throw/breakage, it was seen as a sub-category of the environmental issue “plants”. In contrast to the two other infrastructure types “soil” was only rarely mentioned in road projects.

With regards to high-voltage power transmission lines, “surface water” and “soil” were the most frequently mentioned environmental issues (connected with flooding and erosion) with about two thirds of all hits. Almost 10% of hits referred to “forests”, since this can be associated with damages along overhead transmission lines by strong winds. “Plants” and “animals” were represented with about one fifth of hits overall, while “landscape”, “groundwater”, “biodiversity” and “habitats/bird conservation” (Natura 2000) were represented with only 1% to 5% each.

“Surface water” and “soil” were the most frequently mentioned environmental issues in rail projects, with about 65% of all hits. “Plants” were referred to in about 20% of all hits, followed by “landscape”, “surface water”, “animals” and “air/climate” (together about 15%).

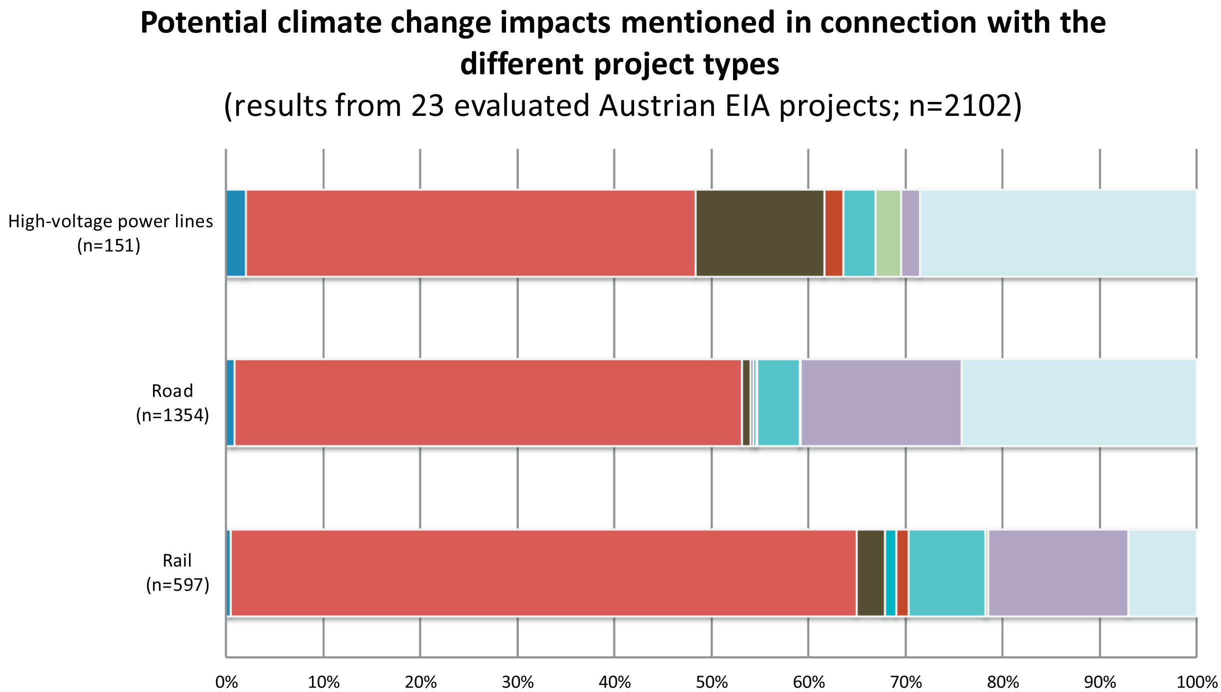
4.2.3. Differences between EIA and technical reports

Some differences were observed in the consideration of meteorological phenomena in EIA and technical reports. In Austria, “heat waves” and “storms” were almost exclusively mentioned in written public statements (i.e. during the final permitting stage). In EISs, one third of the results were associated with “droughts”. In other document types “droughts” represented 10 to 20% of all hits. Changes and amendments in EISs only contained “heavy precipitation”, not mentioning any other meteorological phenomena.

Regarding aspects likely to be affected by CC in the future, in Austria a difference between different types of reports was identified. Technical reports mainly contained hits for “erosion”. However, written public statements included a whole variety of search terms. This was also found when analysing meteorological phenomena.

In Germany, “drought” was mentioned frequently in EISs (85% of hits for this document type) but not in the technical reports. These contained only hits for “heavy precipitation”. In contrast to Austria, the technical reports contained a larger variety of hits for aspects related to CC (“flooding”, “low water levels”, “wind through” and “erosion”). About two thirds of the hits in EISs pertained to “flooding”, followed by about 20% of hits for “erosion” and 10% for “wind throw”.

Differences between the two countries were found with regards to the content of the EISs. In Austria, meteorological phenomena that may be influenced by climate change (CC stressors), and potential CC impacts were mentioned frequently in the description of the current state of the environment and in the assessment of environmental impacts, together making up about 50% of all hits. In the German documents, hits were found in the description of compensation measures (50% of all hits) and in project descriptions (35% of all hits). Only 11% of hits in German documents were from descriptions of the current state of the environment, and 4% from assessments of environmental issues.



	Rail (n=597)	Road (n=1354)	High-voltage power lines (n=151)
Drought	3	11	3
Erosion	385	709	70
Slope slumping	17	12	20
Wet snow		3	
Low water level	7	4	
Storm damages	8	2	3
Flooding	47	59	5
Icing	2	1	4
Wind erosion	86	225	3
Wind throw	42	328	43

Graph 2. Relevant hits of potential CC impacts in Austrian EIA documents.

4.3. Qualitative analysis

All hits on meteorological phenomena (CC stressors) and aspects that could result in potential CC impacts were qualitatively analysed. Those with special relevance for the consideration of CC in EIA were highlighted and are presented in the following two sub-sections. Highly relevant are hits that are presented in combination with studies about CC impacts, impact models (e.g. on heat stress) as well as relevant published work and guidance. Furthermore, hits that signify a high susceptibility of a project to CC in combination with climatic conditions were identified as being highly relevant (e.g. endangered species of wet habitats in pannonic climate with increasing heat and drought periods).

4.3.1. Austrian EIAs

Various meteorological phenomena that may be affected by CC are already addressed in Austrian EIAs. Impacts are increasingly associated with CC and in this context extreme events in particular are addressed. Here, reference is made to natural hazards that directly impact projects and that are relevant for project planning (erosion, heavy rainfall, floods, wind throw, wind erosion, landslides).

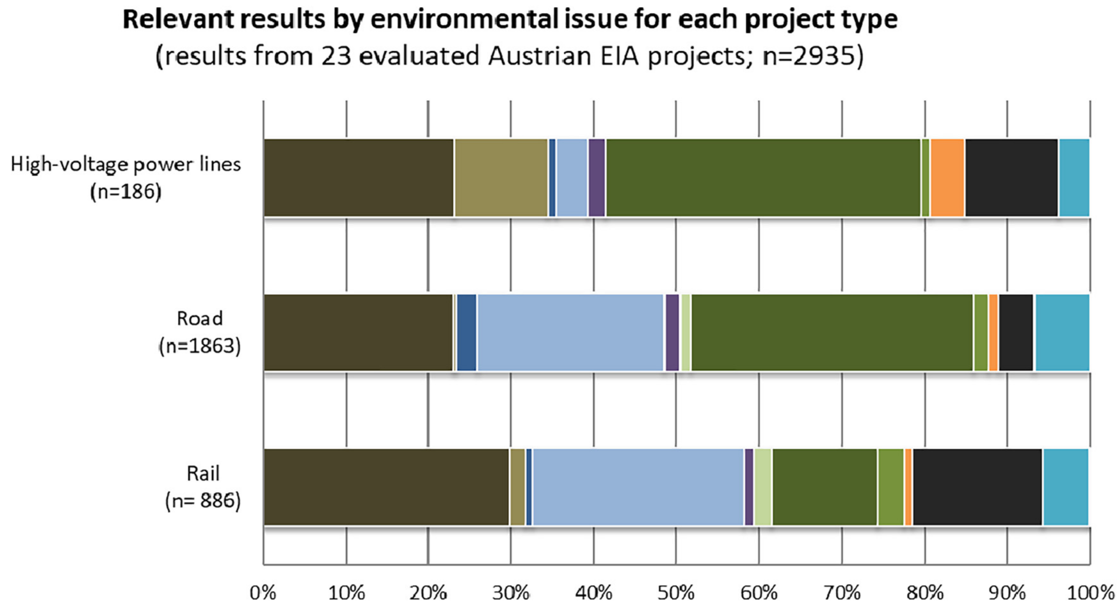
Potential CC impacts were mostly mentioned at one specific stage of an EIA or in one specific file (see Section 4.2.3), but were not followed up or systematically addressed throughout the whole EIA. As the following example illustrates, CC impacts are already included in the assessment of impact intensity (without being explicitly associated with CC, though):

"*The chosen route can lead to unmanageable remaining areas (´glancing intersection´), which could be more susceptible to damages (pests and emission impacts) and wind throw in the following years, due to increased exposure. Aside from a separation of forestry units and plots of land, the length of the forest edge would also increase*" (Lacon/Steinwender, 2015, p. 33).

CC is directly addressed almost exclusively in written statements provided by members of the public. The references made here to CC impacts and prognoses for the future are often very general, but sometimes involve concrete concerns and objections. The following quote provides an example of how the issue of CC is already addressed in such statements:

"*[..] due to the scientifically confirmed increase of heavy rainfall events paired with periods of extreme aridity (Flood-Risk […]). Heavy rainfall events have been increasing dramatically in the area of Drasenhofen/Mikulov since 2006, even 1000-year flood events – extrapolated from 100-year events, since no records are available from 1000 years ago […]. This means that, despite the existence of the two retention basins, the sealing of such a large area upstream of the pheasant garden, approx. more than five hectares, can lead to between a 30-year and 1000-year flood event in the case of heavy rainfall events, such as they are proven to occur in this area in the summer months since 2006 at least as surely as the Amen at the end of a prayer […].*" (BMVIT, 2015, p. 168).

Also, in cases where no references to CC induced impacts were



	Rail (n= 886)	Road (n=1863)	High-voltage power lines (n=186)
Soil	265	428	43
Natural hazards	16	8	21
Ground water	7	46	2
Surface water	228	422	7
animals	10	35	4
Plants	19	25	
Forest	114	637	71
Habitats	28	33	2
Humans	9	23	8
None	139	81	21
Climate/air	50	125	7
Material assets and cultural heritage	1		

Graph 3. Environmental issues addressed in Austrian EIA documents.

Table 6
Total number of results in all documents (Germany) by relevance category.

Search term	Relevant	Low relevance	No relevance	Total
Cold wave			1	1
Slope slumping			1	1
Snow storm		1		1
freezing rain		1	1	2
Drought		1	1	2
Snowfall		2		2
Temperature fluctuation	1			1
Extreme rainfall	1			1
Storm damages	1	2		3
Low water level	2	3	1	6
Icing	3			3
Wind erosion	3	1	2	6
Aridity	7	19	7	33
Wind throw	37	37	72	146
Heavy rainfall	65		14	79
Erosion	75	55	47	177
Flooding	103	160	6	269
Total	**298**	**282**	**153**	**733**

made, yet, this may become relevant in the future, as the following quotes illustrate:

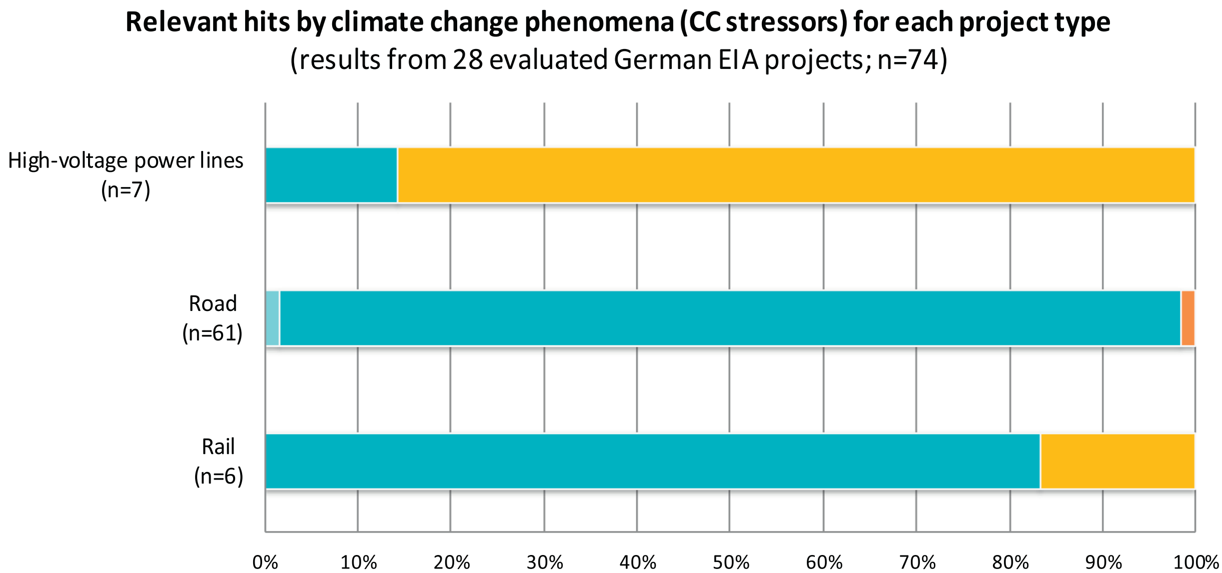
"*(…) problem of extreme weather situations, the 5-year events used as a basis for the project are scarcely sufficient. Thus, regular overloading of the wastewater disposal system is to be expected due to rain and snowfall.*" (BMVIT, 2012, p. 174).

"*All of the surface water on the motorway must be collected and brought to evaporate in evaporation basins. Due to the increased mean annual temperatures, the problem of ´temperature induced aridity´ will become more pressing. The Central Institute for Meteorology and Geodynamics, Vienna, on this matter in March 2012: ´Aridity is most apparent in … the Weinviertel, where it has already been too dry by far for the fifth month in a row. The precipitation deficit between November 2011 and March 2012 is around 70 % over a large part of this area… With a positive deviation of 1.2 °C from the mean of 1971–2000, the year 2011 comes in at number 6 of the warmest years (…).*´" (BMVIT, 2015, p. 51).

In EIA practice, CC relevant aspects were often mentioned directly in the description of mitigation and compensation measures, particularly wind throw hazard, aridity, (wind) erosion and floods. Even though there was no explicit mentioning of the term, the suggested measures are CC adaptations. The following quote regarding the selection of tree species provides an example:

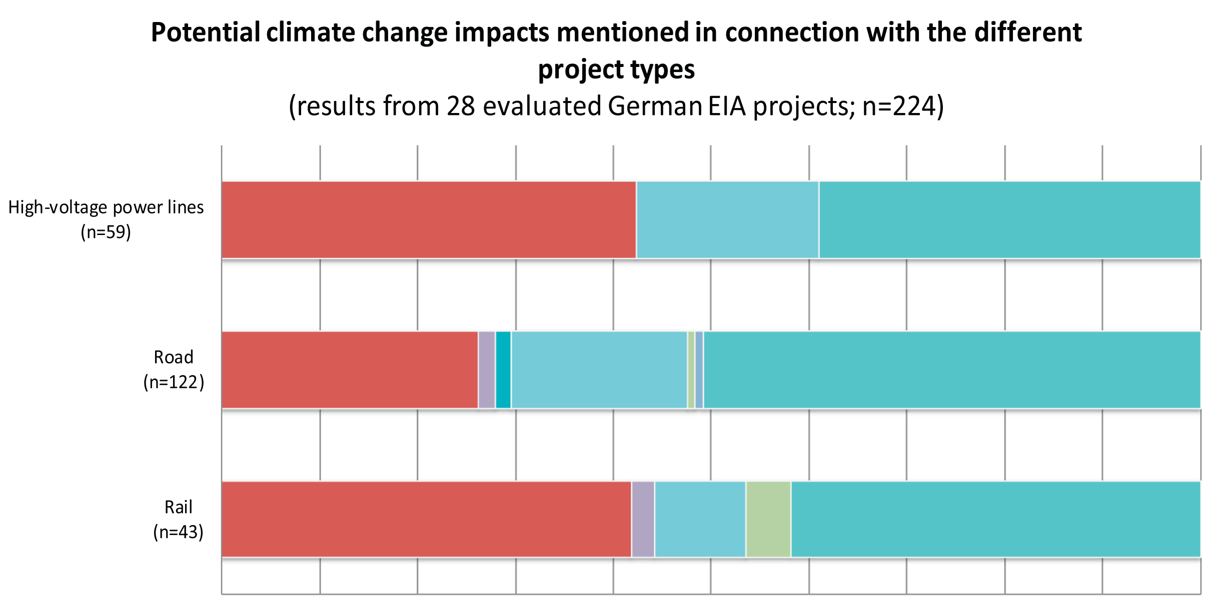
"*Due to a tendency towards aridity in the area, tree species that can deal with this limiting factor have been selected for replacement forestation.*" (Beitl ZT, 2009, p. 65).

In summary, to date potential CC impacts have been rarely recognised, with the exception of some statements by members of the



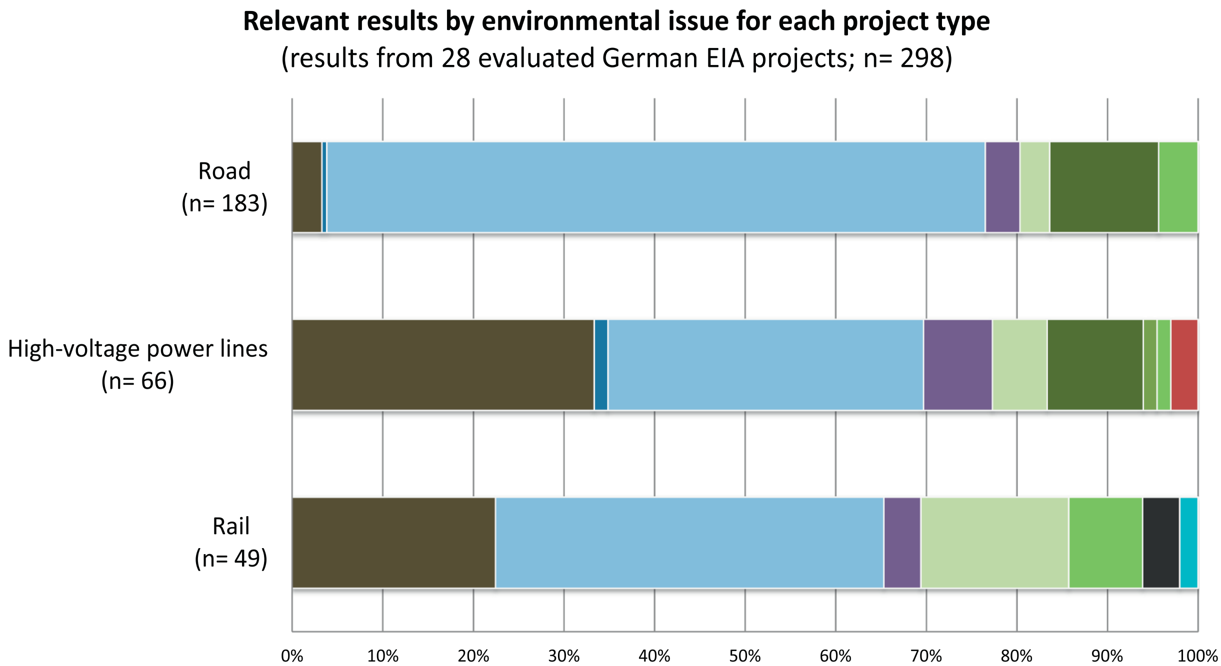
	Rail (n=6)	Road (n=61)	High-voltage power lines (n=7)
Extreme rainfall		1	
Heavy rainfall	5	59	1
Temperature fluctuation		1	
Aridity	1		6

Graph 4. Meteorological phenomena (CC stressors) found in German EIA documents.



	Rail (n=43)	Road (n=122)	High-voltage power lines (n=59)
Erosion	18	32	25
Wind erosion	1	2	
Low water level		2	
Wind throw	4	22	11
Icing	2	1	
Storm damages		1	
Flooding	18	62	23

Graph 5. Potential CC impacts found in German EIA documents.



	Rail (n= 49)	High-voltage power lines (n= 66)	Road (n= 183)
Soil	11	22	6
Ground water		1	1
Surface water	21	23	133
Animals	2	5	7
Plants	8	4	6
Forest		7	22
habitats/bird conservation		1	
Landscape	4	1	8
Biodiversity		2	
None	2		
Climate/air	1		

Graph 6. Environmental issues addressed in German EIA documents.

public as well as authority reviews. However, regarding the development of measures in particular, many of the recommendations and requirements already comply with the objectives of CC adaptation and could be monitored and adjusted with a view to future changes in meteorological phenomena. Therefore, CC adaptation can be said to be considered implicitly.

4.3.2. German EIAs

In German EIAs, to date, CC has been dealt with only rarely. However, there are various examples where meteorological phenomena and aspects that can lead to CC impacts are addressed. One case was identified in which the influence of CC on a project was explicitly discussed (Rhein-Ruhr-Express; Laukhuf et al., 2011; see further below).

Looking at how phenomena and potential CC impacts are distributed across the procedural stages of EIA, CC related aspects have been considered more extensively in the description of the current state of the project and environment reports than in the estimation of impacts and planning of measures. There are examples for every step of EIA, illustrating how CC-relevant aspects are already considered today. In this context, generous timeframes are considered and model based derivations of long-term sensitivities are used. In the case of the Federal motorway A39 project in Lower Saxony, the BERN (carbon cycle) model was used to estimate the development of Natura 2000 habitats under the influence of critical loads and climate change (Planungsgemeinschaft LaReG, 2014). A number of examples from the qualitative analysis shall subsequently be presented. With regards to the current state of the environment in the Federal Road B16 bypass EIA, it is stated that:

"The Danube's flood regime displays an increased discharge in June, which is explained by the higher water levels of the Alpine tributaries (Iller), due to the summer snow and ice melt. The occurrence of these typical flood peaks has shifted to the winter months of December and February outside of the Alpine area." (Lars Consult, 2015a, p. 48).

The question here is how CC can affect winter floods. Extended discharge levels were taken into account to find a bypass alternative which is unlikely to be flooded in the future.

A number of cases addressed the question as to whether planned compensation measures will be able to maintain their full effectiveness in the long term. In the landscape management plan for the A 20 Federal Motorway, reviewers referred to Ministry for Environment guidelines for the selection of tree species, as follows:

"Due to the risk of wind throw, the western part of the poplar forest is to be retained at a width of 30-40 m for the time being, and to be complemented with new plantings of suitable tree species. Autochthonous species from distribution area 1: ´North German Plain´ are to be used, according to the ´Guideline for the use of autochthonous species´ (BMU, 2012). After 10-15 years, approx. 50 % of the poplars will be extracted in groups, thus creating new clearings." (Kortemeier Brockmann Landschaftsarchitekten, 2015, p. 120).

As CC will impact site conditions, the concern is whether the

suggested tree species will find suitable conditions to grow in the long term. A further example stressing the importance of a long-term perspective when planning compensation measures is found in the EIA of the Federal Road 16 bypass at Höchstadt an der Donau:

"*Safeguarding the fen, preventing further erosion, inhibiting advancing mineralisation and regenerating, the original groundwater-based site conditions are essential in this respect. Thus, the measures are aimed at preserving and regenerating the original soil type, which fulfils special functions for the natural vegetation at the site (high conservation development potential) and as a landscape-historical record. They are further aimed at restoring the original hydrological balance and water retention functions (improvement of the soils' function as a compensation body in the water cycle), as well as at reducing the release of CO2 from the body of the fen (contribution to climate protection).*" (Lars Consult, 2015b, p. 73).

Two cases were identified where the monitoring of compensation measures was linked with an obligation to improve measures, should a deviation from the target habitat type be detected. Faced with the uncertainty associated with CC scenarios, such monitoring measures, including mandatory improvements, provide a possible way of dealing with CC in EIA.

In the rail project Rhein-Ruhr-Express, the potential impact of CC on the environmental conditions was evaluated in a "climate change compatibility study". The planning documents contain the following description, pertaining to the project itself and to the planned measures:

"*Climate change-induced changes to environmental conditions can have an impact on railway infrastructure as well as on the compensation measures conceived in the course of the construction/upgrade of the railway infrastructure. For example, a change in the distribution of precipitation can lead to an increase of precipitation on railway infrastructure with the negative consequence of more frequent landslides along the tracks (embankments and excavated slopes). Furthermore, climate change can lead to an increase of deluges and flood events, as well as more frequent heavy rainfall events, which would also have a negative impact on railway infrastructure.*

A further climate change-related factor is an increase of storm events, causing increased wind throw in forests. When conceiving compensation measures under consideration of climate change, the effectiveness of measures must be considered over a period of decades, and must take altered environmental conditions into account […]." (Planungsbüro Laukhuf and Bosch & Partner, 2011, p. 19).

This example used Federal Railway Authority guidelines that stipulate that CC induced impacts on railway infrastructure must be identified (floods, earth movement, slope slumping, and others). These ask for planned measures to be examined with regards to whether they will achieve their ecological objectives, even under CC conditions (EBA, 2014, pp. 13 and 48). The guidelines provide other project types with an example of how to consider CC in EIA.

5. Discussion

To date, CC has been addressed in Austrian and German EIA practice to a limited extent only. Above, we have illustrated a few examples that make explicit reference to potential future changes with likely impacts on the project and/or environmental issue(s). In all cases, inclusion occurred only at specific steps, though, rather than throughout the whole EIA process.

A number of concrete links were made in EIAs of both countries to meteorological phenomena that could be affected (CC stressors), potentially leading to CC impacts. Below, we discuss whether these thematic aspects can serve as entry points for the consideration of CC in the future. Both, the status quo and potential thematic and methodological considerations are considered.

5.1. Integration of CC into projects subject to EIA – status quo

Direct references to CC adaptation are still limited, confirming findings of previous studies such as Hands and Hudson (2016). Relevant statements containing the word "climate/climatic change" were found more frequently in Austrian than German EIAs. One possible explanation is the mountainous topography (60% of the total territory) and the extent of alpine habitats, increasing the susceptibility to CC impacts (also leading to a variety of different potential impacts).[2] Differences related to the types of documents are another explanation (see 4.2.3). The qualitative analysis shows that possible impacts induced by CC are occasionally considered. Usually, however, these aspects are mentioned only once or twice and are neither integrated into the whole EIA process nor into every chapter of the EIS.

Extreme weather events are already frequently considered in EIA. Up to date, however, future changes and especially uncertainties and unforeseen events have only occasionally been integrated in the consideration of environmental issues. While potential CC impacts were considered in Austria almost exclusively for the environmental issues associated with natural hazards (with the exception of wind throw/aridity for the environmental issue habitats/forest), in Germany, nature conservation (Natura 2000 management plans and species protection) is often a driver for sensitivity studies. As the Austrian EIA system follows a one-stop-shop approach, meaning that all permits, e.g. hydrological engineering and geology related, need to be included, Austrian EIAs provide many "entry points" for potential climate proofing. However, only few connections with other environmental issues, such as flora or fauna or hydrobiology were observed.

In Germany, the situation is different, partly because relevant issues are also covered in the statutory landscape planning system (Hanusch and Fischer, 2011). Several guidelines and studies have dealt with the consideration of CC related aspects in landscape planning over the last few years (Doyle et al., 2014; Reck, 2013; May et al., 2016; Streitberger et al., 2016).

Our results suggest that framing conditions (planning system, specific guidance, national adaptation strategies and national policies) can influence the consideration of CC adaptation. However, consideration of international guidance (or studies) can help to identify new thematic entry points, which could become relevant in the future.

With regards to diverse methodological entry points, while in Austrian EIAs, meteorological phenomena and potential CC impacts were mentioned frequently in the description of the current state of and the assessment of impacts on the environment, in German EIAs hits were largely found in the description of mitigation and compensation measures and in project descriptions. Only a minority of hits in German EIAs were from descriptions of the current state of the environment. In both countries, however, the consideration of the likely development in the future with regards to a changing climate was usually missing.

5.2. Entry points for the consideration of CC connected with environmental issues

In Germany and Austria, soil, water and flora – in particular forest habitats – were associated most frequently with future CC impacts. The frequency and intensity of impacts on environmental issues varied according to the project type and the topographical/climatic conditions. However, any additional aspects relevant to CC will also affect other environmental issues, such as fauna and biodiversity or human health.

In both countries, practice considers natural hazards but not an increased susceptibility of humans or flora/fauna to CC. Partially, existing standards have been adapted due to (potentially) more frequent future occurrences of extreme events. However, only recently has the introduction of an endangered species index (suggested by the Environment Agency Austria) been discussed, highlighting increased susceptibilities to CC. Generally speaking, the only direct reference to

[2] Not only does the topography differ between the two countries but also the climatic conditions. Germany has coastal areas with a maritime climate in the North and Austria has a continental climate, in the South bordering to Mediterranean climate zones.

CC adaptation made in guidelines was to adaptation strategies, both, at Federal and *Länder* (state) levels. However, these documents are currently unspecific. The German guidelines by the Federal Railway Authority (EBA, 2014) also ask for CC impacts to be considered in all sections of an EIS and encourage consideration in the development of compensation and mitigation measures. Furthermore, the guidelines for the consideration of CC in landscape planning (May et al., 2016) suggest detailed entry points for CC adaptation that are of relevance for EIA.

5.3. Possible entry points for the consideration of CC impacts in EIA

Results pertaining to meteorological phenomena and potential CC impacts differed between Austria and Germany, even though the three most relevant phenomena (CC stressors) were the same, including “heavy rainfall”, “storms” and “aridity”. Differences can be attributed to the different climatic and topographic conditions in both countries, highlighting the importance of geography and wider context. Generally speaking, the topics receiving the greatest attention in EIA in both countries, and which are potential entry points for consideration of future CC impacts, include “erosion”,” flooding”, “wind throw”, “drought”, “slope slumping” and “wind erosion”. Topics such as “low water levels” and “icing” are relevant but currently not much addressed. Furthermore, there are aspects relevant to CC that have been rarely mentioned, but which we believe merit greater attention. These are “forest and slope fires”, “temperature fluctuation”, “heavy snowfall with wet snow” and “freeze/thaw weather” with an increased potential of “slope erosion” (see Table 1).

With regards to environmental issues, our analysis revealed several thematic entry points. We therefore suggest that there should be new requirements for integrating CC impacts into EIA in both countries. In the case of soil, water and human health/natural hazards, changes in existing models/guidelines (e.g. flooding and landslide models, including “vulnerability analyses”/”risk analyses”) are necessary and are currently receiving increased attention. New topics are also arising for “flora/fauna/habitats” through the consideration of CC relevant aspects. To date, these have only been rarely covered. Here, documents framing practice (e.g. guidance) and planning systems (nature projection management plans, river basin management plans, landscape plans, thematic regulations etc.) can serve as entry points.

With regards to the methodological entry points, it is the development of mitigation and compensation measures that can support an ability to react to changes after project realisation. Our analysis shows that several common mitigation and compensation measures can be redimensioned or adapted (e.g. the selection of more heat and drought resistant tree species), whereas for some potential CC impacts new strategies need to be sought and new approaches to monitoring the effectiveness of measures are needed. In this context, an “adaptive monitoring” (Byron and Brown, 2013, EC, 2013a) may be suitable, which is already practiced in German wind power EIAs (Bulling and Köppel, 2017). Descriptions of the current state of the environment addressed topics that could be highly relevant for CC. Future studies/models/scenarios brought forward by the zero-alternative will be of particular importance.

6. Conclusions and outlook

Direct consideration of CC adaptation is still the exception in Austrian and German EIA practice. Our results therefore confirm findings of previous studies that were conducted in other countries. However, changes to meteorological phenomena – depicted in the international literature as CC stressors – are already frequently addressed in both countries. Various meteorological data (on e.g. precipitation and wind) are often integrated directly into Austrian and German EIAs. Potential impacts – which might be influenced by CC in the future – are also addressed with regards to a number of environmental issues. Only few of these thematic considerations integrated CC projections or impact models, though. Our findings indicate that there may be a number of thematic entry points for CC adaptation when addressing future changes of regional and local frequency and intensity of these phenomena.

Considering the revised European EIA Directive, those environmental issues likely to be most susceptible to natural hazards include soil, water and forest habitats. However, other potential future CC impacts, including draughts and changed average temperatures might affect the susceptibility of other environmental issues. These will need to receive increased attention, in particular by environmental authorities as well as in standards and guidelines. For the three types of infrastructure projects covered in this paper, consideration of changes is particularly important due to their long life-time. In its guidance documents, the European Commission (2013a and 2017) has stressed the importance of a long-term view on CC impacts. The diverse susceptibility of the environment to CC is currently only rarely addressed in the evaluation of the current state of the environment. Additional methodological entry points for the consideration of CC adaptation therefore deserve further attention. Models of CC impacts and spatially resolved data in particular are important for considering potential future changes, as was illustrated in municipal planning contexts (Archie et al., 2014). Accessibility to them is important as was pointed out e.g. by Goosen et al. (2014) as well as Vaughan and Dessai (2014). Depending on the planning context, this could either mean integrating climate scenarios into existing models (e.g. flood risk maps, change of areas/habitats) or, if such models are not available, scenarios of changes of meteorological phenomena can serve as entry points to include CC in EIA in case no specific models for potential CC impacts are available.

It is not only the accessibility of CC related data (or the facilitation of climate projections by climate services) which is essential to reduce barriers for the consideration of CC adaptation but also the extent of engagement in topics relevant to climate change (Räsänen et al., 2017). In this context, topics discussed in past EIAs could serve as a starting point in a specific country context. A broader international perspective may be important in order to identify newly relevant aspects, including those that will become relevant only under changed climatic conditions. Further investigations of other project types could help establishing additional entry points for relevant thematic aspects.

Our analysis revealed that environmental authorities and the public are already aware of CC related issues, starting to discuss future developments under CC conditions. However, as EIA in both countries is based on agreed quality standards and conventions, it will only be possible to consider CC fully if vulnerability models are available for specific topics for each environmental issue.

Acknowledgement

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Annex: Overview of EIAs

Project name	Time frame	Length
Federal road projects (Germany)		
A 94 München - Pocking	2016	12.3 km
A 20 Westerstede – Jaderberg, Abschnitt 1	2016	13 km
A 20 Bremervörde – Elm, Abschnitt 6	2016	12.4 km
A 39 Lüneburg, Abschnitt 1	2016	7.7 km
A 39 Ehra – Wolfsburg, Abschnitt 7	2016	14.2 km
A 14 Magdeburg – Schwerin, VKE 1.5	2015	12.9 km
B 16 Ortsumfahrung Höchstädt a.d. Donau	2016	7.0 km
B 90 Frössen – Bad Lobenstein	2015	5.5 km
B10 Neubau 2. Rheinbrücke Karlsruhe/Wörth am Rhein	2015	3.7 km
Railway projects (Germany)		
NBS Stuttgart 21 - Augsburg, TA 1.3a	2016	9.4 km
Schönbuchbahn, PFA 2 bis 4	2014	ca. 15 km
RRX Rhein-Ruhr-Express, PFA 1.1	2011	4.32 km
Eisenach-Gerstungen, PFA 1	2016	4.2 km
ESTW-R Bernburg, Dessau Hbf – Köthen	2015	41 km
Oldenburg-Wilhelmshaven, PFA 1	2015	8.9 km
PFA 7 Sande - Wilhelmshaven	2015	6.5 km
Power grid projects (Germany)		
Ganderkesee - St. Hülfe, 2. Abschnitt	2016	61 km
Wehrendorf - Gütersloh, 3. Abschnitt	2013	27 km
Osterrath - Weissenthurm, 1. Abschnitt	2012	30 km
Osterrath - Weissenthurm, 3. Abschnitt	2011	35 km
Südwestkuppelleitung, 1. Abschnitt	2007	165 km
Südwestkuppelleitung, 2. Abschnitt	2012	57 km
Südwestkuppelleitung, 3. Abschnitt	2013	26 km
Wesel – Meppen, 1. Abschnitt	2011	15 km
Wesel – Meppen, 2. Abschnitt	2011	11 km
Wesel – Meppen, 3. Abschnitt	2014	13 km
Wesel – Meppen, 7. Abschnitt	2011	56 km
Stendal – Wolmirstedt, 4. Abschnitt	2014	37 km

Project name	Time Frame	Length
Power grid projects (Austria)		
380-kV-Salzburgleitung, Netzknoten St. Peter – Netzknoten Tauern	2012–2015	113 km (380 kV) 14 km (220 kV)
380-kV-Freileitung St. Peter nach Deutschland	2014–2015	2.5 km
Railway projects (Austria)		
Wien Hauptbahnhof - Verkehrsprojekt Schiene	2007–2008	
Brenner Basistunnel	2008–2013	55 km
Pottendorfer Linie - zweigleisiger Ausbau Abschnitt Hennersdorf-Münchendorf	2009–2016	13 km
ÖBB-Strecke Schwarzach-St. Veit bis Villach Hbf. Abschnitt Schlossbachgraben – Angertal	2009	1.7 km
Semmering Basistunnel neu	2010–2014	27 km
Verbindung Ostbahn – Flughafenschnellbahn	2010–2011	2 km
Terminal Wien Inzersdorf	2010–2012	3.3 km
ÖBB-Strecke 221 - Linz Hauptbahnhof bis Summerau	2011	61.2 km
Umbau Linz Hbf - Westseite	2011	
3-gleisiger Ausbau Freilassing – Salzburg Neubau, Saalachbrücke	2010–2012	1.5 km
ÖBB-Strecke 117 Stadlau – Staatsgrenze n. Marchegg, Ausbau und Elektrifizierung	2013–2015	37 km
Zweigleisiger Ausbau der Pottendorfer Linie (ÖBB-Strecke Wien Matzleinsdorf – Wr. Neustadt) Abschnitt Ebreichsdorf	2015	10.6 km
Federal road projects (Austria)		
S 10 Mühlviertler Schnellstraße, Abschn. Süd, Unterweitersdorf - Freistadt Nord	2007–2012	22.3 km
S 7 Fürstenfelder Schnellstraße, Abschnitt West, Riegersdorf (A2) – Dobersdorf	2008–2015	14.8 km
S 7 Fürstenfelder Schnellstraße Abschnitt Ost (Dobersdorf – Heiligenkreuz)	2009–2016	13.6 km
S 1 Wiener Außenring Schnellstraße Abschnitt Schwechat - Süßenbrunn (S1 Lobau)	2004–2015	19 km
A 5 Nord Autobahn Abschnitt Schrick – Poysbrunn	2005–2013	24.7 km

A 5 Nord Autobahn Abschnitt Poysbrunn – Staatsgrenze	2005–2015	10 km
A 26 Linzer Autobahn Abschnitt Süd (Knoten Linz/Hummelhof (A7) bis AST Donau Nord	2007–2014	4,3 km
S 1 Wiener Außenring Schnellstraße Abschnitt A5/B7 bis Knoten Korneuburg A22/S1	2007	
S 3 Weinviertler Schnellstraße Hollabrunn – Guntersdorf	2012–2015	

References

Agrawala, S., Kramer, A.M., Prudent-Richard, G., Sainsbury, M., 2010. Incorporating Climate Change Impacts and Adaptation in Environmental Impact Assessments Opportunities and Challenges. OECD Environmental Working Paper No. 24. OECD Publishing.

Archie, K.M., Dilling, L., Milford, J.B., Pampel, F.C., 2014. Unpacking the 'information barrier': comparing perspectives on information as a barrier to climate change adaptation in the interior mountain West. J. Environ. Manag. 133, 397–410.

Balla, S., Schönthaler, K., Wachter, T. & Peters H.-J., 2017. Grundlagen der Berücksichtigung des Klimawandels in UVP und SUP. Analyse, Bewertung und Politikempfehlungen zur Anpassung nationaler rechtlicher, planerischer und informatorischer Politikinstrumente an den Klimawandel – 1. Teilbericht Arbeitspaket 4 des FE-Vorhabens FKZ 3713 48 105 im Auftrag des Umweltbundesamts, in prep. Climate Change 2017.

Beitl, Z.T., 2009. Fachbericht Forstwirtschaft und Waldökologie. Linie - zweigleisiger Ausbau Abschnitt Hennersdorf – Münchendorf, Pottendorfer.

Bhave, A.G., Conway, D., Dessai, S., Stainforth, D.A., 2016. Barriers and opportunities for robust decision making approaches to support climate change adaptation in the developing world. Climate Risk Manag. 14, 1–10.

Birkmann, J., Schanze, J., Müller, P., Stock, M. (Eds.), 2012. Anpassung an den Klimawandel durch räumliche Planung Grundlagen. Instrumente, Strategien E-Paper der ARL Nr. 13. Hannover.

Bles, T., Bessembinder, J., Chevreuil, M., Danielsson, P., Falemo, S., Venmans, A., 2015. In: The CliPDaR Consortium (Ed.), Roads for today, adapted for tomorrow Guidelines, . http://www.transport-research.info/sites/default/files/project/documents/ROADAPT_integrating_main_guidelines.pdf.

BMLFUW - Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2017. Die österreichische Strategie zur Anpassung an den Klimawandel. Aktualisierte Fassung.

BMU – Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2009. Dem Klimawandel begegnen. Die deutsche Anpassungsstrategie, Berlin.

BMU – Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2011. Aktionsplan Anpassung der Deutschen Anpassungsstrategie an den Klimawandel vom Bundeskabinett am 31. August 2011 beschlossen. https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/anpassung-auf-bundesebene/aktionsplan-anpassung.

BMVBS – Bundesministerium für Verkehr, Bau und Stadtentwicklung (Ed.), 2013. Methodenhandbuch zur regionalen Klimafolgenbewertung in der räumlichen Planung. Systematisierung der Grundlagen regionalplanerischer Klimafolgenbewertung, Berlin.

BMVIT – Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2012. UVGA Stellungnahmen, S1 Wiener Außenring Schnellstraße Abschnitt Schwechat - Süßenbrunn (S1 Lobau).

BMVIT – Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2015. Auseinandersetzung mit Stellungnahmen, A5 Nord Autobahn Abschnitt Poysbrunn - Staatsgrenze (A5 Nord B).

Born, M., Heidrich, B., Spiekermann, J., (n.d.). Klimaanpassung in Planungsverfahren – Leitfaden für die Stadt- und Regionalplanung. FE-Vorhaben Klimawandel Unterweser - Mit dem Klimawandel handeln! - Akteursorientierte Risikokommunikation im Umgang mit ungesichertem Wissen der Fördermaßnahme klimazwei – Forschung für den Klimaschutz und Schutz vor Klimawirkungen des BMBF.

Boyle, J., Cunningham, M., Dekens, J., 2013. Climate Change Adaptation and Canadian Infrastructure. A Review of the Literature. International Institute for Sustainable Development, Winnipeg.

Bulling, L., Köppel, J., 2017. "Adaptive Management" in der Windenergieplanung. Eine Chance für den Artenschutz in Deutschland? Naturschutz Landschaftsplanung 49 (2), 73–79.

Byer, P., Cestti, R., Croal, P., Fisher, W., Hazell, S., Kolhoff, A., Kornov, L., 2012. Climate Change in Impact Assessment – International Best Practice Principles IAIA Special Publication Series No. 8. USA: International Association for Impact Assessment. Cornish E. Futuring: the exploration of the future. World Future Society, Bethesda, MD 2004 (313pp.).

Byron, K., Brown, E., 2013. Adaptive management: from more talk to real action. Environ. Manag. 52 (6). http://dx.doi.org/10.1007/s00267-013-0205-7.

CARICOM - Caribbean Community Secretariat, 2004. Guide to the Integration of Climate Change Adaptation into the Environmental Impact Assessment (EIA) Process.

CEAA - Canadian Environmental Assessment Agency, 2003. Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners. The Federal-Provincial Committee on Climate Change and Environmental Assessment.

Dallhammer, E., Formayer, H., Jiricka, A., Keringer, F., Leitner, M., McCallum, S., Schmied, J., Stanzer, G., Völler, S., 2015. ENVironmental Impact assessment Satisfying Adaption Goals Evolving from Climate Change, publish-ready final report. Financed by: ACRP, Klima- und Energiefonds. pp. 31.

Department for Transport, 2014. Transport Resilience Review. A Review of the Resilience of the Transport Network to Extreme Weather Events. Secretary of State for Transport, UK.

Doyle, U., Ristow, M., Vohland, K., 2014. Abschwächung von klimabedingten Naturkatastrophen - wie Naturschutzstrategien dazu beitragen können. Natur und Landschaft 89 (12), 522–526.

Draaijers, G., van der Velden, A., 2009. The NCEA's Recommendations on Climate Change in Environmental Assessment. Netherlands Commission for Environmental Assessment. http://web.law.columbia.edu/sites/default/files/microsites/climate-change/netherlands.pdf.

EBA – Eisenbahnbundesamt, 2014. Umwelt-Leitfaden zur eisenbahnrechtlichen Planfeststellung und Plangenehmigung sowie für Magnetschwebebahnen. In: Teil III Umweltverträglichkeitsprüfung – Naturschutzrechtliche Eingriffsregelung.

EC - European Commission, 2013a. Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment. http://ec.europa.eu/environment/eia/pdf/EIA%20Guidance.pdf.

EC - European Commission, 2013b. Adapting infrastructure to climate change. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. An EU Strategy on adaptation to climate change. SWD (2013) 137 final. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013SC0137&from=en.

EC - European Commission, 2013c. The EU Strategy on Adaptation to Climate Change. Strengthening Europe's resilience to the impacts of climate change. https://ec.europa.eu/clima/sites/clima/files/docs/eu_strategy_en.pdf.

EC - European Commission, 2017. Strategic Environmental Assessment in EU Development Cooperation. In: A Handful of Tips to Get it Right!, . https://europa.eu/capacity4dev/file/67040/download?token=k2GvJ1T0.

Enríquez-de-Salamanca, A., Martín-Aranda, R.M., Díaz-Sierra, R., 2016. Consideration of climate change on environmental impact assessment in Spain. Environ. Impact Assess. Rev. 57, 31–39.

Enríquez-de-Salamanca, A., Díaz-Sierra, R., Martín-Aranda, R.M., Santos, M.J., 2017. Environmental impacts of climate change adaptation. Environ. Impact Assess. Rev. 64 (2017), 87–96.

Environmental Assessment Team, 2010. In: The Scottish Government (Ed.), Consideration of Climatic Factors within Strategic Environmental Assessment (SEA), . https://www.historicenvironment.scot/media/2383/0096207.pdf.

European EIA-Directive, 2014. Directive 2014/52/EU of the European Parliament and of the Council of 16 April.

European Environment Agency, 2017. Climate change adaptation and disaster risk reduction in Europe. Enhancing coherence of the knowledge base, policies and practices. https://www.eea.europa.eu/publications/climate-change-adaptation-and-disaster/at_download/file.

Fischer, T.B., Sykes, O., 2009. The new EU territorial agenda - indicating progress for climate change mitigation and adaptation? In: Davoudi, S. (Ed.), Planning for Climate Change. Earthscan, pp. 111–124.

Fischer, T.B., Potter, K., Donaldson, S., Scott, T., 2011. Municipal waste management strategies, strategic environmental assessment and the consideration of climate change in England. J. Environ. Assess. Policy Manag. 13 (4), 541–565.

Fischer, T.B., Therivel, R., Bond, A., Fothergill, J., Marshall, R., 2016. The revised EIA directive – possible implications for practice in England. UVP Rep. 30 (2), 106–112. http://www.uvp.de/de/uvp-report/jg30/jg30h2/866-uvp-report-030-19.

Goosen, H., de Groot-Reichwein, M. A. M., Masselink, L., Koekoek, A., Swart, R., Bessembinder, J., Witte, J. M. P., Stuyt, L., Blom-Zandstra, G., Immerzeel, W., 2014. Climate Adaptation Services for the Netherlands: an operational approach to support spatial adaptation planning. Reg. Environ. Change 14, 1035–1048. https://doi.org/10.1007/s10113-013-0513-8.

Hands, S., Hudson, M.D., 2016. Incorporating climate change mitigation and adaptation into environmental impact assessment: a review of current practice within transport projects in England. Impact Assess. Project Apprais. 34 (4), 330–345.

Hanusch, M., Fischer, T.B., 2011. SEA and landscape planning. In: Sadler, B., Aschemann, R., Dusik, J., Fischer, T.B., Partidário, M., Verheem, R. (Eds.), Handbook of Strategic Environmental Assessment. Earthscan, London, pp. 173–257.

Infrastructure Canada, 2006. Adapting infrastructure to climate change in Canada's cities and communities. A literature review. In: Research & Analysis Division.

Jacoby, C., Beutler, K., 2013. Konzeptioneller Leitfaden – Integration einer Klimafolgenabschätzung in die Umweltprüfung zum Flächennutzungsplan am Beispiel der Flächennutzungsplanung mit integrierter Landschaftsplanung der Stadt Regensburg. (Entwurf der lokalen Forschungsassistenz für das vom BMVBS/BBSR geförderte StadtKlima ExWoSt-Vorhaben der Stadt Regensburg).

Jiricka, A., Völler, S., Leitner, M., Formayer, H., Fischer, T.B., Wachter, T.F., 2014. Herausforderungen bei der Integration von Klimawandelfolgen und -anpassung in Umweltverträglichkeitsprüfungen - ein Blick auf die Planungspraxis in Österreich und Deutschland. UVP Rep. 28 (3+4), 179–185.

Jiricka, A., Formayer, H., Schmidt, A., Voller, S., Leitner, M., Fischer, T.B., Wachter, T.F., 2018. Consideration of climate change impacts and adaptation in EIA practice - perspectives of actors in Austria and Germany. Environ. Impact Assess. Rev. 57 (2016), 78–88.

Jiricka-Pürrer, A., Leitner, M., Formayer, H., Wachter, T., Prutsch, A., 2018.

Mainstreaming climate change adaptation in infrastructure planning – Lessons learned from knowledge transfer and communication. In: Leal, W., Lackner, B. (Eds.), Addressing the challenges in communicating climate change across various audiences. Springer.

Kamau, J.W., Mwaura, F., 2013. Climate change adaptation and EIA studies in Kenya. Int. J. Clim. Change Strategies Manage. 5 (2), 152–165.

Koetse, M.J., Rietveld, P., 2009. The impact of climate change and weather on transport: an overview of empirical findings. Transp. Res. D 14, 205–221.

Kortemeier Brockmann Landschaftsarchitekten, 2015. Landschaftspflegerische Maßnahmen, Bundesautobahn A 20. Abschnitt 1.

Kunze, K., van Haaren, C., Reich, M., Weiß, C., 2014. Kompensationsflächenmanagement im Klimawandel – Anpassungsmaßnahmen im Bremer Feuchtgrünland zur Erhaltung von Ökosystemleistungen und Empfehlungen für die Eingriffsregelung. In: Korn, H., Bockmühl, K., Schliep, R. (Eds.), Biodiversität und Klima – Vernetzung der Akteure in Deutschland X – Ergebnisse und Dokumentation des 10. Workshops. BfN-Skripten, pp. 357.

Lacon/Steinwender, 2015. Fachbericht Forstwirtschaft, S7 Fürstenfelder Schnellstraße, Abschnitt Ost, Dobersdorf bis Heiligenkreuz (Staatsgrenze).

Lars Consult, 2015a. Umweltverträglichkeitsstudie, Bundestraße 16 Ortsumfahrung Höchstadt a. d. Donau.

Lars Consult, 2015b. Landschaftspflegerischer Begleitplan, Bundestraße 16 Ortsumfahrung Höchstadt a. d. Donau.

Larsen, S.V., 2014. Is environmental impact assessment fulfilling its potential? The case of climate change in renewable energy projects. Impact Assess. Project Apprais. 32 (3), 234–240.

Laukhuf, Planungsbüro, Bosch, Partner, 2011. Allgemein verständliche, nichttechnische Zusammenfassung nach § 6 UVPG, Rhein-Ruhr-Express PFA 1.1.

May, A., Arndt, P., Radtke, L., Heiland, S., 2016. In: Leitfaden, Ein, LUBW Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (Eds.), Kommunale Klimaanpassung durch die Landschaftsplanung, . http://www.fachdokumente.lubw.baden-wuerttemberg.de/servlet/is/91063/.

McCallum, S., Dworak, T., Prutsch, A., Kent, N., Mysiak, J., Bosello, F., Klostermann, J., Dlugolecki, A., Williams, E., König, M., Leitner, M., Miller, K., Harley, M., Smithers, R., Berglund, M., Glas, N., Romanovska, L., van de Sandt, K., Bachschmidt, R., Völler, S., Horrocks, L., 2013. Support to the Development of the EU Strategy for Adaptation to Climate Change: Background Report to the Impact Assessment, Part I – Problem Definition, Policy Context and Assessment of Policy Options. Environment Agency, Vienna, Austria.

MKRO – Ministerkonferenz für Raumordnung, 2013. Handlungskonzept der Raumordnung zu Vermeidungs-, Minderungs- und Anpassungsstrategien in Hinblick auf die räumlichen Konsequenzen des Klimawandels.

Nemry, F., Demirel, H., 2012. Impacts of climate change: A focus on road and rail transport infrastructures. In: JRC Scientific and Policy Reports. European Union, Luxembourg.

Nova Scotia Environment (Canada), 2011. Guide to Considering Climate Change in Environmental Assessments in Nova Scotia. https://novascotia.ca/nse/ea/docs/EA.Climate.Change.Guide.pdf.

Integrating climate change adaptation into development co-operation. In: OECD, Policy Guidance (Eds.), OECD's Environment.

Planungsgemeinschaft LaReG, 2014. Landschaftspflegerische Maßnahmen. Maßnahmenblätter, A 39 Abschnitt 7 Lüneburg.

Räsänen, A., Jurgilevicha, A., Haanpääc, S., Heikkinena, M., Groundstroema, F., Juholaac, S., 2017. The need for non-climate services – empirical evidence from Finnish municipalities. Clim. Risk Manag. 16 (2017), 29–42.

Reck, H., 2013. Klimawandel, Biodiversität und Kompensation – Maßnahmen für die Zukunft. Natur und Landschaft 88 (11), 447–452.

Regmi, M.B., Hanaoka, S., 2011. A survey on impacts of climate change on road transport infrastructure and adaptation strategies in Asia. Environ. Econ. Policy Stud. 13, 21–41.

Roll, E., Hauke, C., Kowallik, C., Lüdeke, J., Neises, F., Rommel, S., Steudel, D. 2014. Umwelt-Leitfaden zur eisenbahnrechtlichen Planfest-stellung und Plangenehmigung sowie für Magnetschwebebahnen. Teil III Umweltverträglichkeitsprüfung – Naturschutzrechtliche Eingriffsregelung; Hrsg. Eisenbahnbundesamt; https://www.eba.bund.de/DE/HauptNavi/Infrastruktur/Planfeststellung/Umweltbelange/umweltbelange_node.html.

Runge, K., Wachter, T., 2010a. Umweltfolgenprüfung von Klimaanpassungsmaßnahmen. Nat. schutz Landsch. Plan. 42 (5), 141–147.

Runge, K., Wachter, T., 2010b. Umweltfolgenprüfung von Klimaanpassungsmaßnahmen. Naturschutz und Landschaftsplanung 42 (5), 141–147.

Runge, K., Wachter, T., Rottgart, E., 2010. Klimaanpassung, climate proofing und Umweltfolgenprüfung. UVP Rep. 24 (4), 165–169.

Anpassung an den Klimawandel in der räumlichen Planung. In: Spiekermann, J., Franck, E. (Eds.), Handlungsempfehlungen für die niedersächsische Planungspraxis auf Landes- und Bundesebene, Arbeitsberichte der ARL Nr. 11. Hannover.

Streitberger, M., Ackermann, W., Fartmann, T., Kriegel, G., Ruff, A., Balzer, S., Nehring, S., 2016. Artenschutz unter Klimawandel: Perspektiven für ein zukunftsfähiges Handlungskonzept. In: Naturschutz und Biologische Vielfalt 147. Godesberg, Bonn-Bad.

Swart, R., Biesbroek, R., 2008. Adaptation of Infrastructure to Climate Change: International Inventory (in Dutch). Alterra/Wageningen University and Research Centre.

UNECE Water, 2009. In: United Nations Economic Commission (Ed.), Guidance on water and adaptation to climate change, . https://www.unece.org/fileadmin/DAM/env/water/.../Guidance_water_climate.pdf.

Vaughan, C., Dessai, S., 2014. Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. Wiley Interdis. Rev. 5, 587–603. https://doi.org/10.1002/wcc.290.

Wachter, T.F., Balla, S., Schönthaler, K., 2017. Methodische Empfehlungen zur Berücksichtigung des Klimawandels in der Umweltverträglichkeitsprüfung. UVP Rep. 31 (3), 213–223.

Walker, W.E., Haasnoot, M., Kwakkel, J.H., 2013. Adapt or Perish: A review of planning approaches for adaptation under deep uncertainty — overview on key approach. In: Audience and Content Framework.